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Spatial Structure and Temporal Variation of Fish Communities in the Upper Mississippi River System

May 2005

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Spatial Structure and Temporal Variation of Fish Communities in the Upper Mississippi River System

BY

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is implemented by the Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS as both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multuse character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

This report supports Task 2.2.8 as specified in Goal 2, *Monitor Resource Change*, of the LTRMP Operating Plan (U.S. Fish and Wildlife Service 1993). This report was developed with funding provided by the LTRMP.

Spatial Structure and Temporal Variation of Fish Communities in the Upper Mississippi River System

by

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Abstract: Variation in community composition (presence/absence data) and structure (relative abundance) of Upper Mississippi River fishes was assessed using data from the Long Term Resource Monitoring Program collected from 1994 to 2002. Community composition of fishes varied more in space than through time. We found substantial variation in community composition across two spatial scales: large-scale differences between upper and lower river reaches and small-scale differences among individual regional trend areas (RTA). Community structure (relative abundance data) of fishes also varied more through space than through time. We found substantial variation in fish community structure at three spatial scales: (1) large-scale differences between upper and lower river reaches, (2) differences among individual RTA, and (3) differences among habitat strata, with backwaters having a distinct community structure relative to the main channel and side channels. When averaged across all RTA, fish community structure in 1994 and 1995 was distinct from all other years, possibly as a result of the 1993 Flood. Fish community structure observations for each RTA and year correlated with the environmental variables measured at each sample site. A canonical approach revealed that the combination of Secchi depth, water temperature, current velocity, and vegetation abundance had the greatest correlation with community structure.

Key words: fish communities, LTRMP, ordination, spatial scale, Upper Mississippi River System

Introduction

The Long Term Resource Monitoring Program (LTRMP) was authorized by the Water Resources Development Act of 1986 as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The primary mission of the LTRMP is to provide river managers and the public with ecological information necessary to maintain the Upper Mississippi River System (UMRS) as a viable multiuse ecosystem. Four long-term goals have been established for the LTRMP: (1) increase understanding of how the river ecosystem operates, (2) monitor the status and trends of UMRS natural resources, (3) assist in the development and evaluation of management alternatives, and (4) manage and provide access to resulting data, information, and products (U.S. Army Corps of Engineers 1997). A critical tool for achieving these goals is standardized monitoring of four key ecosystem components—water quality, aquatic vegetation, aquatic macroinvertebrates, and fish—at five regional trend areas (RTA) on the Mississippi River and one RTA on the Illinois River. Central to the objectives of LTRMP are the ability to detect long-term trends for these key components, and the ability to correlate these trends with environmental variables to gain insight into possible cause-and-effect relations.

Fishes are one of the most important goods and services that rivers provide to humans. Upper Mississippi River fishes are the subject of commercial and recreational fisheries, both of which contribute substantially to local economies. For example, recreation on the Upper Mississippi River alone has been estimated to provide 18,000 jobs and generate $1.2 billion in our economy per year and recreational fishing is a key component of this economic activity (Carlson et al. 1995; Sparks et al. 1998). Fish communities are frequently used as indicators of ecological integrity for large-river ecosystems because of their diversity and their response to environmental variation at multiple scales (Gammon and Simon 2000; Schiemer 2000; Schmutz et al. 2000). Therefore, the ability to detect variation in the composition and structure of fish communities is a desirable feature of long-term monitoring programs in large-river ecosystems.

We used LTRMP fish data from 1994 to 2002 to examine shifts in the composition (presence/absence of species) and structure (relative abundance of species) of fish communities in the UMRS. Our analyses of community composition relied on presence/absence data from a combination of five gears: day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets (Gutreuter et al. 1995). To assess patterns in fish community structure, we relied on data from day electrofishing, and we also developed a multigear index of community structure and analyzed this to complement the information gained from the more conservative analysis of day electrofishing data alone. Finally, we used multivariate correlation techniques to assess whether any patterns of the measured environmental variables were correlated with observed fish community patterns.

Methods

We analyzed fish data collected by the LTRMP from 1994 to 2002 (1993 was excluded from these analyses because of incomplete data collection). This program monitors fish communities in six RTA in the Upper Mississippi River System: Pools 4, 8, 13, and 26, La Grange Pool of the Illinois River, and an open river reach (Open River Reach; Figure 1). We relied on two sets of data for our analyses: (1) day electrofishing catch-per-unit-effort (CPUE; number collected per 15 min), which has been shown to have power to detect changes for the greatest number of species relative to all

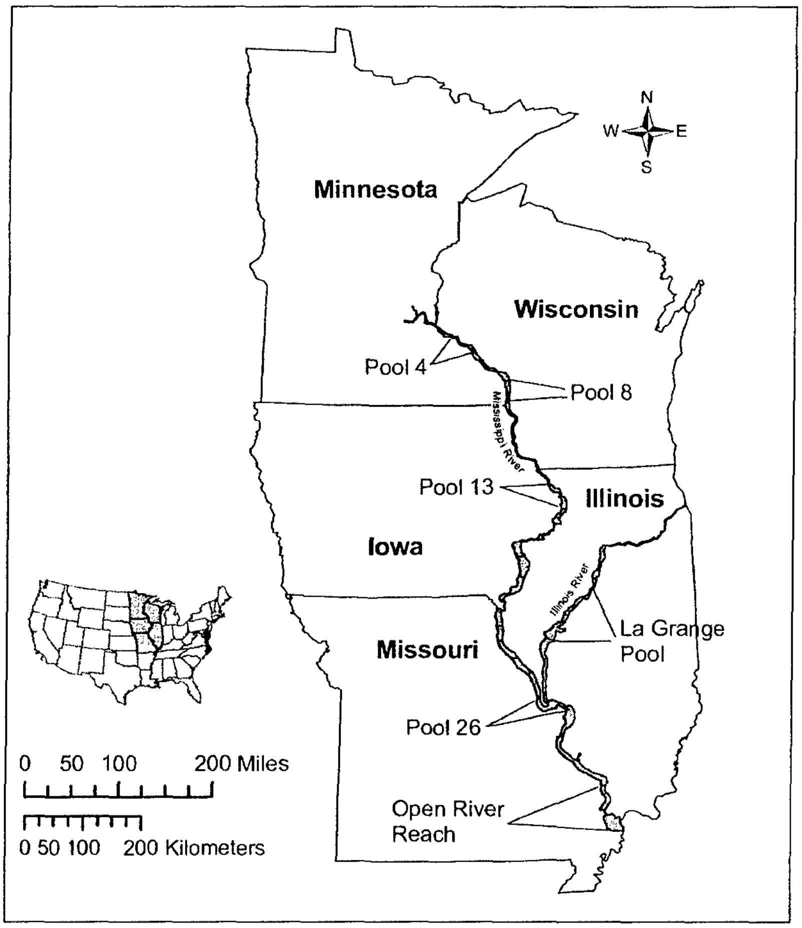

Figure 1. Map of the Upper Mississippi River System showing the six regional trend areas (Pools 4, 8, 13, and 26, La Grange Pool, and Open River Reach) in light grey for the Long Term Resource Monitoring Program.

the collection methods used in the LTRMP (Lubinski et al. 2001); and (2) a combination of total catch data from day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets to provide more complete data on species composition and community structure. Collection methodology are published elsewhere (Gutreuter et al. 1995) and will be only briefly summarized below. For all gears, data were collected using a stratified random design, where the main channel borders, side channels, contiguous backwaters, and impounded areas constitute unique strata. Sites are selected at random from each stratum, allowing for the computation of poolwide averages that are weighted by the total area of each stratum within each RTA.

Day electrofishing was conducted using pulsed-DC output with two ring anodes, and the boat hull served as the cathode. Two dippers collected fishes, and voltage and amperage were adjusted for water temperature and conductivity to achieve a power output of 3,000 W. Day electrofishing was conducted continuously along shorelines for 15 min at each sample site.

Large and small hoop nets were set in paired deployments. Large hoop nets were 4.8 m long and included seven fiberglass hoops. The first hoop was 1.2 m in diameter and successive hoops decreased in diameter incrementally by 2.5 cm. Two throats were attached, one to the second hoop and one to the fourth hoop, and the mesh size was 3.7 cm in diameter. Small hoop nets were 3 m long, had seven hoops (first hoop was 0.6 m in diameter, successive hoops decreased in diameter by 2.5 cm), and the mesh size was 2.5 cm. Large and small hoop nets were baited with 3 kg of soybean cake and were deployed for 48 hours. Hoop nets were set so that the open end (first hoop) was facing downstream in water of sufficient depth to submerge all of the throats.

Fyke and mini-fyke nets were Wisconsin-type trap nets comprised of three sections: (1) a rectangular frame, (2) a cab section within the frame comprised of six hoops that led to the cod end, and (3) a lead, which was a bar of mesh that extended from the frame to the shoreline. For fyke nets, the lead was 15 m long and 1.3 m high, the frame was 1.8 × 6 m, the cab was formed from 0.9-m steel hoops, and the mesh size was 1.8 cm. For mini-fyke nets, the lead was 4.5 m long and 0.6 m high, the frame was 1.2 × 3 m, the cab was formed by two 0.6-m diameter hoops, and the mesh size was 3 mm. Fyke and mini-fyke nets were set with the lead extended perpendicular to the shoreline. Water depth at the frame had to be sufficient to submerge the throats and nets were fished for 24 hours.

For all collection methods, a series of standard physical and chemical measurements were made at the initiation of sampling (Table 1). Water depth was recorded from a depth-finder, and Secchi depth was recorded to the nearest centimeter. Water temperature was measured to the nearest 0.1°C, conductivity was measured in µS/cm using a YSI Conductivity Meter (YSI, Inc., Yellow Springs, OH), and current velocity was measured to the nearest 0.01 m/s. Additionally, qualitative assessments of percent

Table 1. Habitat variables routinely collected from each electrofishing site for the Long Term Resource Monitoring Program (Gutreuter et al. 1995).

Habitat factor	Units	Explanation
Secchi	cm	
Conductivity	µS/cm	
Flow (surface velocity)	m/s	
Water temperature	°C	
Depth	m	
Vegetation coverage	0, 1, 2, 3	0 = 0% coverage; 1 = 1-19% coverage 2 = 20-49% coverage; 3 = 50% coverage
Vegetation density	0, 1, 2	0 = no vegetation; 1 = sparse; 2 = dense
Substrate	1, 2, 3, 4	1 = silt; 2 = silt/clay/little sand 3 = sand/mostly sand; 4 = gravel/rock/hard clay
Woody structure	presence/absence	presence/absence of woody structure
Revetment	presence/absence	presence/absence of shoreline revetment
Inlet/outlet	presence/absence	presence/absence on an inlet/outlet channel to a backwater lake
Flooded terrestrial vegetation	presence/absence	presence/absence of flooded terrestrial vegetation

aquatic vegetation coverage and density, substrate type, and other habitat factors were recorded (Table 1).

Analyses

We analyzed variation of community composition through space and time using presence/absence data from a combination of day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets. Because some species were not well sampled by any of these gears, we eliminated any species where <20 individuals were collected when summed across all RTA and years. This resulted in analyses being conducted on presence/absence data from a total of 100 fishes. Hybrids and fishes not identified to species were eliminated from these analyses. Presence/absence data were summarized for each RTA and year, and a similarity matrix was constructed based on Euclidean distance. All analyses were performed using the Primer version 5 software package (Primer-E Ltd 2001).

We used Analysis of Similarity (ANOSIM) to test for significant variation among RTA and years. Analysis of similarity is analogous to univariate Analysis of Variance (ANOVA) which tests for significant differences among groups. Unlike ANOVA, however, ANOSIM is based on a similarity matrix rather than raw data, and significance is based on comparisons of this matrix to random permutations of the matrix (Clarke and Warwick 1994). Two test statistics are provided by ANOSIM, an R statistic that reflects the amount of dissimilarity associated with each factor (analogous to the R^2 statistic from ANOVA) and a P value that indicates whether R (range -1 to 1) is significantly different from zero. Both R and P are important to consider because it is possible for R to be significantly different from zero but still inconsequentially small (Clarke and Warwick 1994). Our analyses tested for variation of the fish community among RTA when averaged across all years and variation among years when averaged across all RTA. Nonmetric multidimensional scaling (NMDS) was used to identify groupings of observations, and a similarity breakdown (SIMPER procedure in Primer; Primer-E Ltd 2001) was used to identify the species contributing to the dissimilarity among the groups identified with NMDS.

Variation in community structure was analyzed from day electrofishing CPUE data and from standardized total catch data from the combination of day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets. For day electrofishing, we limited the species used to a group of 16 for which electrofishing had power ≥0.80 to detect a 20% interannual abundance change in at least one habitat stratum of at least one RTA based on the Lubinski et al. (2001) power analysis. This conservative criteria was adopted to help ensure that the patterns of relative abundance used in these analyses reflect true ecological patterns rather than sampling artifacts. Hybrids and fishes not identified to species were omitted from these analyses.

Because of the large size of the UMRS and its physical complexity, no single gear effectively samples the entire UMRS fish community. Thus, we chose to include data from five gear types (day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets) simultaneously to permit the broadest definition of the UMRS fish community as possible. However, each gear differed notably in its selectivity characteristics (Ickes and Burkhardt 2002), potentially complicating our approach. Our solution capitalized on the highly standardized nature of the LTRMP sampling protocols. Within a RTA, proportional gear allocations were constant over time (years). Although the individual gears used in our analyses differ in their selectivity, the combined selectivity of the five gear types remains constant over time within a river reach. By placing data from each gear on the same scale (standardization) and calculating separate multigear indexes for each study reach and year, we ensure that no single gear overly influenced our results while allowing the broadest definition of community as possible. Furthermore, the use of poolwide estimates of mean CPUE weighted by habitat strata should minimize differences in abundance estimates arising from variation of gear allocation among RTA.

Annual mean CPUE estimates were compiled for each collected species from all RTA, years, and gear types. For each gear, we limited the species used in these analyses to those for which power ≥0.80 to detect a 20% interannual abundance change in at least one habitat stratum of at least one RTA (Lubinski et al. 2001). Under this criteria, a total of 37 fishes were included in these analyses. We arranged data from each gear in a matrix with species (n = 37) comprising the rows and RTA (n = 6) and year (n = 10) combinations comprising the columns. We then calculated a total catch for each row (i.e., summed CPUE across species) and calculated the grand mean total catch (GMTC) for each gear type. To place CPUE data from each gear on the same relative scale, we divided CPUE from each species, RTA, and year combination by the appropriate GMTC for that particular gear. This standardization places all observations on the same scale (proportion of GMTC) while maintaining all of the species abundance relations within a RTA-year combination and all differences among RTA-year combinations within a species. Finally, we summed the standardized mean CPUE estimates for all five gear types together for each RTA and year combination resulting in a 37 × 60 matrix, to arrive at a multigear index of community structure.

We used ANOSIM to test for variation in community structure (day electrofishing CPUE and multigear index) among RTA when averaged across years and for variation among years when averaged across RTA. We used NMDS to identify groupings of observations. Analysis of similarity and NMDS were based on Bray-Curtis similarity matrices. Two analyses were conducted examining different spatial scales. In the first, observations consisted of RTA-stratum-year combinations. In the second, observations consisted of RTA-year combinations. Furthermore, we examined temporal patterns across all RTA by averaging the standardized catch data from the multigear index across RTA for each year. For the analysis of day electrofishing data among RTA and years, a similarity breakdown was used to identify the species contributing most to the dissimilarity among groups. We did not conduct a similarity breakdown for the multigear index because the efficacy of this approach has not been examined on a species-by-species basis.

Finally, we used the electrofishing data to examine whether spatial and temporal variation in fish community structure corresponded with variation in the environmental factors collected from each sample site. The two categorical vegetation measures—percent cover and density (Table 1)—were multiplied to form one variable representing overall abundance of aquatic vegetation. We calculated a normalized (mean = 0, standard deviation = 1) Euclidean distance matrix from the habitat variables, and a Mantel test was used to determine whether this correlated with the Bray-Curtis similarity matrix from fish community structure data. A canonical Mantel test (BioEnv procedure in Primer; Clarke and Warwick 1994) was used to determine the combination of habitat variables that provided the greatest correlation with community data.

Results

Community Composition

We found notable spatial variation of community composition at two scales. Community composition varied significantly among river reaches (R = 0.92; P < 0.001) and years (R = 0.13; P = 0.019), but the relatively small R value associated with among year differences suggests that most of the dissimilarity among observations was due to spatial variation. Nonmetric multidimensional scaling revealed spatial groupings at two scales: upper and lower river reaches and individual RTA. The greatest variation was between upper and lower river reaches (Figure 2). Also, community composition overlapped substantially among the three upper RTA whereas the three lower RTA each formed separate and fairly distinct groups (Figure 2). Five fish species—burbot (*Lota lota*), spotted sucker (*Minytrema melanops*), weed shiner (*Notropis texanus*), western sand darter (*Ammocrypta clara*), and central mudminnow (*Umbra limi*)—were collected only in upper river reaches. Nineteen species were collected only in the lower river reaches (Table 2). The similarity breakdown showed that 31 species contributed more than 90% of the dissimilarity among the three lower RTA (Table 3).

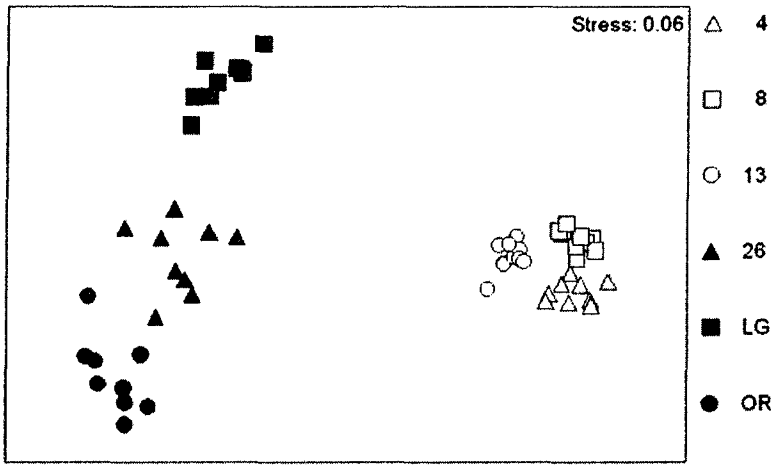

Figure 2. Nonmetric multidimensional scaling ordination of fish community composition data (presence/absence) for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Data were from a combination of day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets. Each point represents community composition for a single year within the designated regional trend area. Ecological similarity was measured using the Euclidean Distance metric. The upper resource trend areas (Pools 4, 8, and 13) are represented by open symbols whereas the lower resource trend areas (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols. 4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool, and OR = Open River Reach.

Community Structure

We found notable variation in community structure at three spatial scales. Community structure of fishes collected using day electrofishing varied significantly among RTA (R = 0.840; $P < 0.001$) and stratum (R = 0.532; $P < 0.001$). Nonmetric multidimensional scaling revealed little overlap between upper and lower river reaches (Figure 3). Pool 8 was disassociated from the other upper RTA, and the Open River Reach was somewhat distinct from the other lower reaches. Pools 4 and 13 showed considerable overlap as did Pool 26 and La Grange Pool (Figure 3). When the samples are coded according to stratum, backwaters were fairly distinct from the main channel borders and side channels, which overlapped considerably (Figure 4). A total of 12 species accounted for more than 90% of the dissimilarity between backwaters and the main channel or side channels. Gizzard shad (*Dorosoma cepedianum*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), common carp (*Cyprinus carpio*), smallmouth buffalo (*Ictiobus bubalus*), black crappie (*Pomoxis nigromaculatus*), bullhead minnow (*Pimephales vigilax*), and freshwater drum (*Aplodinotus grunniens*) were more abundant in backwaters. Emerald shiner (*Notropis atherinoides*), spotfin shiner (*Cyprinella spiloptera*), white bass (*Morone chrysops*), and shorthead redhorse (*Moxostoma macrolepidotum*) were more abundant in the main channel borders and side channels.

We also found substantial variation in community structure among river reaches when annual poolwide averages of CPUE were analyzed. Community structure varied significantly among RTA (R = 0.83; $P < 0.001$) and years (R = 0.226; $P = 0.001$), but the relatively small R associated with years suggests that most of the dissimilarity among our data was associated with differences among river reaches. Nonmetric multidimensional scaling revealed little overlap between upper and lower

Table 2. Common and scientific names for 19 fishes found only in the lower regional trend areas (Pool 26, La Grange Pool, and Open River Reach).

Common name	Scientific name
Bighead carp	*Hypopthalmichthys nobilis*
Blue catfish	*Ictalurus furcatus*
Blacktail shiner	*Cyprinella venusta*
Blackstripe topminnow	*Fundulus notatus*
Freckled madtom	*Noturus nocturnus*
Goldfish	*Carassius auratus*
Grass carp	*Ctenopharyngodon idella*
Inland silverside	*Menidia beryllina*
Longear sunfish	*Lepomis megalotis*
Western mosquitofish	*Gambusia affinis*
Red shiner	*Cyprinella lutrensis*
Redear sunfish	*Lepomis microlophus*
Silverband shiner	*Notropis shumardi*
Striped bass	*Morone saxatilis*
Skipjack herring	*Alosa chrysochloris*
Spotted bass	*Micropterus punctulatus*
Silver carp	*Hypothalmichthys molitrix*
Threadfin shad	*Dorosoma petenense*
White perch	*Morone americana*

Table 3. Presence/absence data for 31 fishes contributing to compositional differences among the three lower regional trend areas (26 = Pool 26, LG = La Grange Pool, and OR = Open River Reach).

Common name	Scientific name	Pools collected in
Trout perch	*Percopsis omiscomaycus*	OR
River redhorse	*Moxostoma carinatum*	OR
Pugnose minnow	*Opsopoeodus emiliae*	OR
Bluntnose darter	*Etheostoma chlorosoma*	OR
Mimic shiner	*Notropis volucellus*	OR
Inland silverside	*Menidia beryllina*	OR
Blacktail shiner	*Cyprinella venusta*	OR
Spotted bass	*Micropterus punctulatus*	OR
Silver lamprey	*Ichthyomyzon unicuspis*	26
Rock bass	*Ambloplites rupestris*	LG
Yellow perch	*Perca flavescens*	LG
Northern hog sucker	*Hypentelium nigricans*	LG
Pumpkinseed	*Lepomis gibbosus*	LG
Highfin carpsucker	*Carpiodes velifer*	LG
Silver redhorse	*Moxostoma anisurum*	LG
White perch	*Morone americana*	LG
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	26, OR
Speckled chub	*Macrhybopsis aestivalis*	26, OR
River darter	*Percina shumardi*	26, OR
Mississippi slivery minnow	*Hybognathus nuchalis*	26, OR
Spotfin shiner	*Cyprinella spiloptera*	26, OR
Channel shiner	*Notropis wickliffi*	26, OR
Grass pickerel	*Esox americanus vermiculatus*	26, LG
Northern pike	*E. lucius*	26, LG
Brown bullhead	*Ameiurus nebulosus*	26, LG
Striped bass	*Morone saxatilis*	LG, OR
White sucker	*Catostomus commersoni*	LG, OR
Longear sunfish	*Lepomis megalotis*	LG, OR
Johnny darter	*Etheostoma nigrum*	LG, OR
Fathead minnow	*Pimephales promelas*	LG, OR
Pirate perch	*Aphredoderus sayanus*	LG, OR

RTA (Figure 5). Furthermore, four groups were apparent: A, Pool 8; B, Pools 4 and 13; C, Pool 26 and La Grange Pool; and D, the Open River Reach. The similarity breakdown revealed that 13 species accounted for more than 90% of dissimilarity between upper and lower groups. Emerald shiner, bluegill, largemouth bass, spotfin shiner, bullhead minnow, shorthead redhorse, and silver redhorse (*Moxostoma anisurum*) were more abundant in the upper river reaches, whereas gizzard shad, common carp, channel catfish (*Ictalurus punctatus*), smallmouth buffalo, white bass, and freshwater drum were more abundant in the lower river reaches. Fourteen species accounted for more than 90% of dissimilarity among groups (Table 4). Group A had the greatest abundance of bluegill, spotfin shiner, largemouth bass, bullhead minnow, shorthead redhorse, silver redhorse, and black crappie. Group B had the greatest abundance of emerald shiner, and group C had the greatest abundance of gizzard shad, common carp, freshwater drum, white bass, smallmouth and bigmouth buffalo (*Ictiobus cyprinellus*).

Analysis of community structure using the multigear index revealed more defined differences among the six RTA and greater temporal variation. Community composition varied significantly among RTA ($R = 0.793$; $P < 0.001$) and years ($R = 0.324$; $P < 0.001$). As with our analyses of day electrofishing data alone, NMDS revealed little overlap of upper and lower river reaches and each of the six RTA were fairly distinct (Figure 6). When data were averaged by year across the six RTA, 1994 was disassociated from all other years (Figure 7), and a group of seven species—common carp, black crappie, channel catfish, bluegill, emerald shiner, gizzard shad, and smallmouth buffalo—were associated strongly with variation among years (Figure 8). Some of these species decreased after 1994, whereas others increased after 1994 (Figure 9).

Community Structure—Environmental Relationships

Similarity among RTA and years in community structure was significantly correlated with environmental variables (Mantel $R = 0.60$; $P < 0.001$). Canonical Mantel correlations showed the greatest correlation ($R = 0.76$) with a combination of Secchi disk transparency, water temperature, current velocity, and vegetation abundance. Upper RTA had greater abundance of aquatic vegetation and deeper Secchi depths. Lower RTA had faster current velocity and higher temperature (Figure 10).

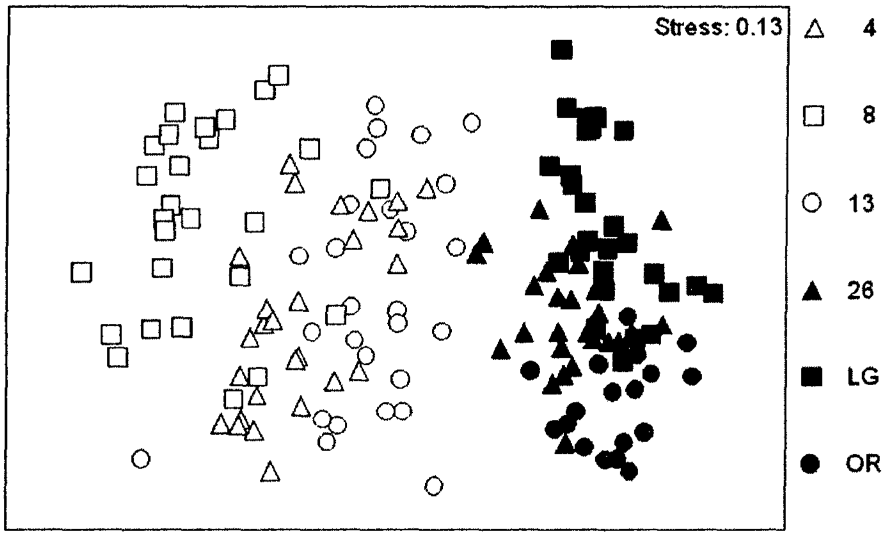

Figure 3. Nonmetric multidimensional scaling ordination of fish community structure data (square root catch/15 min of day electrofishing) for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Each point represents fish community structure for a combination of year and habitat strata within the designated regional trend area. Ecological similarity was measured using the Bray-Curtis Similarity metric. The upper resource trend areas (Pools 4, 8, and 13) are represented by open symbols whereas the lower resource trend areas (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols. 4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool, and OR = Open River Reach.

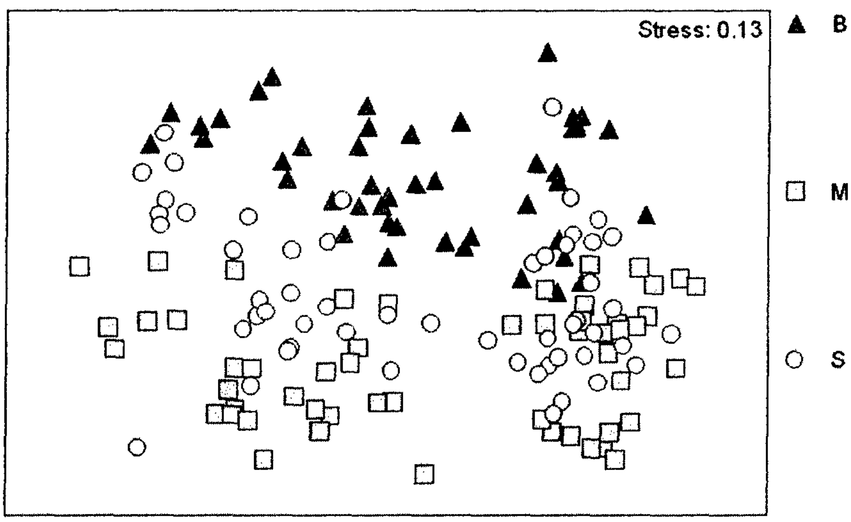

Figure 4. Nonmetric multidimensional scaling ordination of fish community structure data (square root catch/15 min of day electrofishing) for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Each point represents fish community structure for a combination of year and habitat strata within the designated regional trend area. Ecological similarity was measured using the Bray-Curtis Similarity metric. The ordination is identical to Figure 3 (year × habitat strata × resource trend area) but with points coded by habitat strata (B = backwaters, M = main channel, and S = side channel) rather than resource trend area.

Discussion

Community structure and composition of UMRS fishes varied more in space than in time. Our analyses suggest a hierarchy of spatial variation. Observations first grouped according to large-scale differences between upper and lower river reaches, then grouped at smaller scales including individual RTA or groups of RTA, and finally grouped according to habitat stratum. For these data, temporal patterns were largely limited to variation among observations within spatial groupings. If systemic temporal trends of a magnitude greater than the observed spatial variation had been prevalent, our observations would have grouped first by year and then by spatial groupings. Our observations that spatial variation of UMRS fish communities were predominate over temporal variation may appear trivial, but have important implications for understanding the ecology of this system and for the design of research and monitoring programs.

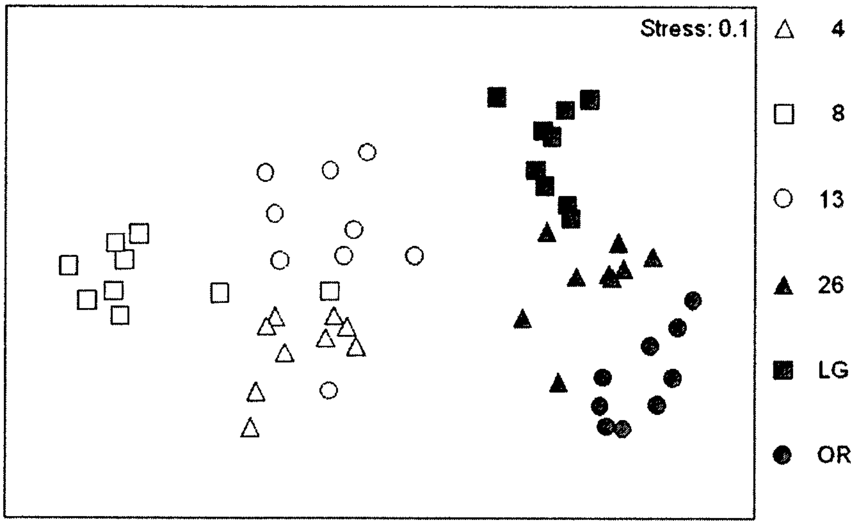

Figure 5. Nonmetric multidimensional scaling ordination of fish community structure data (square root catch/15 min of day electrofishing) for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Each point represents community structure (based on poolwide means) for a single year within the designated regional trend area. Ecological similarity was measured using the Bray-Curtis Similarity metric. The upper resource trend areas (Pools 4, 8, and 13) are represented by open symbols whereas the lower resource trend areas (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols. 4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool and OR = Open River Reach.

For example, the stratified random design used in the LTRMP stratifies by habitat, whereas our analyses demonstrated that fish communities varied more across larger spatial scales (e.g., RTA and upper and lower reaches).

The most consistent pattern observed in our analyses of community composition and structure was a clear separation of the upper three RTA from the lower RTA. Similar results were found in a 1-year study that extended LTRMP day electrofishing to river reaches upstream and downstream of three RTA (Chick and Pegg 2004). Two previous studies also found distinct differences between upper and lower UMRS reaches based on habitat variables (U.S. Geological Survey 1999; Koel 2001). Similar spatial patterns of fish community structure have also been observed in the Missouri and Illinois Rivers (Pegg and Pierce 2002; Pegg and McClellend 2004). Geographic range limitations of fishes probably influenced our community composition results, as several species reach the northern or southern limits of their range in the lower or upper portion of the UMRS. Additionally, habitat factors and possibly contemporary and/or historical barriers to migration probably influenced differences in fish composition and community structure between upper and lower reaches. Upper river reaches had deeper Secchi depths and greater abundance of

Table 4. Mean catch-per-unit-effort (square root catch/15 min) of 14 species of fish accounting for more than 90% of the dissimilarity among the groups (A = Pool 8; B = Pools 4 and 13; C = Pool 26 and La Grange Pool; and D = Open River Reach).

Species	Scientific name	Group			
		A	B	C	D
Gizzard shad	*Dorosoma petenense*	1.72	3.51	7.13	5.83
Bluegill	*Lepomis macrochirus*	5.21	3.04	1.43	0.22
Spotfin shiner	*Cyprinella spiloptera*	2.99	0.84	0.18	0.01
Bullhead minnow	*Pimephales vigilax*	2.58	0.71	0.21	0.06
Largemouth bass	*Micropterus salmoides*	2.94	2.06	0.83	0.03
Emerald shiner	*Notropis atherinoides*	2.46	2.62	1.31	1.49
Common carp	*Cyprinus carpio*	1.43	2.22	3.11	1.55
Shorthead redhorse	*Moxostoma macrolepidotum*	1.3	0.77	0.14	0.01
Freshwater drum	*Aplodinotus grunniens*	0.41	0.98	1.61	1.11
Silver redhorse	*Moxostoma anisurum*	0.99	0.48	0	0
Smallmouth buffalo	*Ictiobus bubalus*	0.09	0.38	1.4	0.45
White bass	*Morone chrysops*	0.49	0.84	1.64	0.95
Bigmouth buffalo	*Ictiobus cyprinellus*	0.05	0.15	0.68	0.15
Black crappie	*Pomoxis nigromaculatus*	0.8	0.76	0.52	0.04

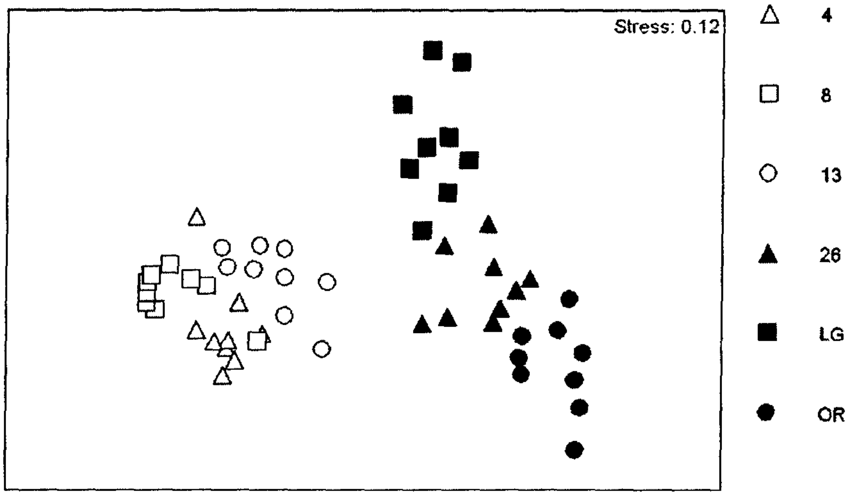

Figure 6. Nonmetric multidimensional scaling ordination of fish community structure data and indexed by multiple gears for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Each point represents community structure for a single year within the designated resource trend area. Ecological similarity was measured using the Bray-Curtis Similarity metric. The upper resource trend areas (Pools 4, 8, and 13) are represented by open symbols whereas the lower resource trend areas (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols. 4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool, and OR = Open River Reach.

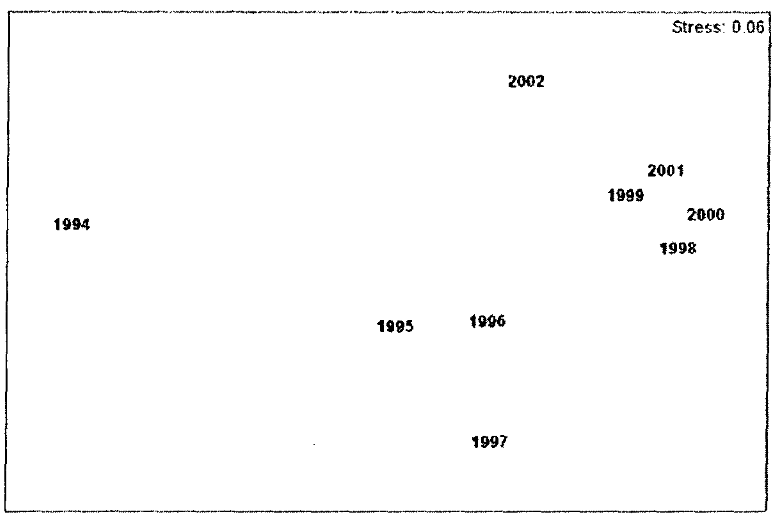

Figure 7. Nonmetric multidimensional scaling ordination of fish community structure data, indexed by multiple gears, and averaged by year across all resource trend areas for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Ecological similarity was measured using the Bray-Curtis Similarity metric. Labels reflect the averaged community structure for each year.

aquatic vegetation compared to lower river reaches, whereas lower river reaches had faster current velocity and higher water temperature.

In addition to differences between upper and lower river reaches, there were differences in fish communities among RTA and stratum. Differences among RTA were significant in every analysis conducted. Community composition was more variable among the three lower RTA than among the three upper RTA. In our analyses of day electrofishing data, some overlap in community structure was apparent for Pools 4 and 13, as well as for Pool 26 and La Grange Pool. We used fairly conservative criteria for the inclusion of species in this analysis. Our multigear analyses, which included a total of 81 species, showed more distinct groupings of observations for each of the RTA. As expected, fish community structure differed among strata, but this variation was less important than variation between upper and lower river reaches, and variation among RTA.

Classification systems recognizing major habitat types, such as main channel borders, side channels, and backwaters, are fundamental to the study of large rivers (Welcomme 1979, 1985). As a result, monitoring programs and ecological studies conducted on large river systems (including the LTRMP) often explicitly incorporate these habitat types into

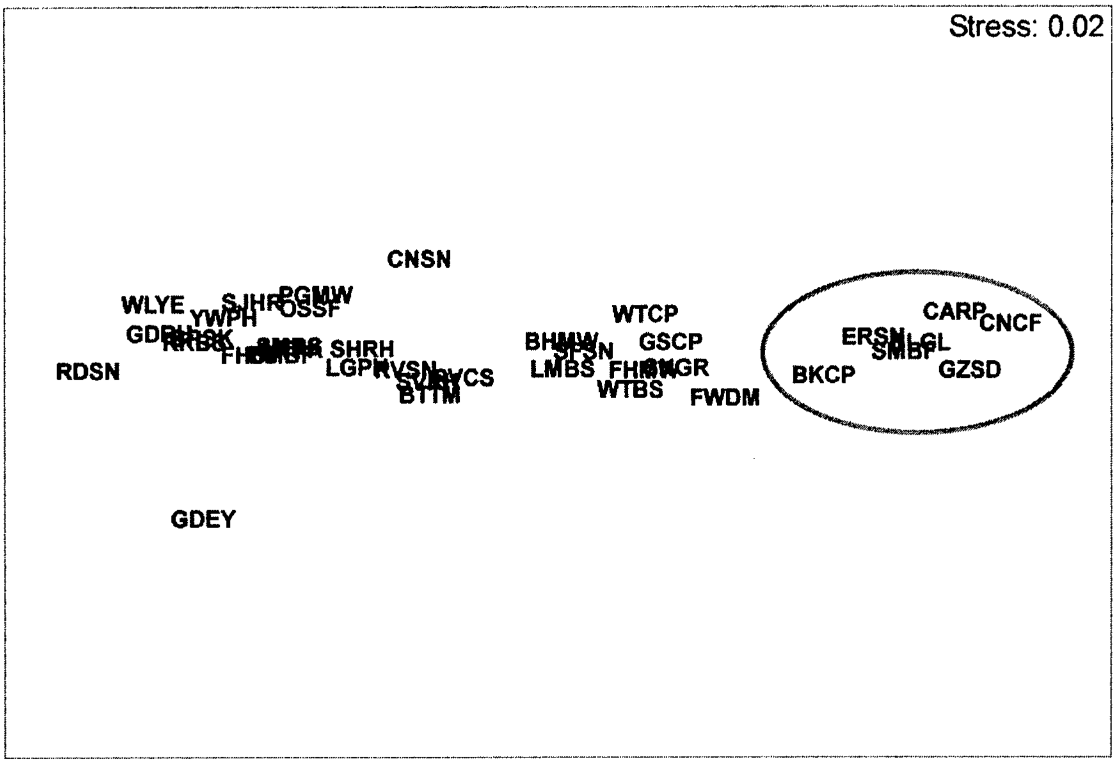

Figure 8. Nonmetric multidimensional scaling ordination of fish community structure data, indexed by multiple gears, and averaged by year across all resource trend areas for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Ecological similarity was measured using the Bray-Curtis Similarity metric. Each point represents one species, with information averaged across regional trend areas. Species grouping closely together varied similarly through time. Labels reflect the four-digit letter codes used to identify species by the Long Term Resource Monitoring Program (Gutreuter et al. 1995). The circle encloses seven fish species (BKCP = black crappie [*Pomoxis nigromaculatus*], BLGL = bluegill [*Lepomis macrochirus*], CARP = common carp , [*Cyprinus carpio*] CNCF = channel catfish [*Ictalurus punctatus*], ERSN = emerald shiner [*Notropis atherinoides*], GZSD = gizzard shad [*Dorosoma cepedianum*]) that are grouping disjunctively from all other species, suggesting stronger variation through time for these species.

their experimental design. Variation of fish communities at larger spatial scales is less understood. Much of the variance in UMRS fish communities was associated with large spatial scales, suggesting that our understanding of the dynamics of fish communities in the UMRS and other large river systems probably would benefit from focused investigations into the factors contributing to these patterns. What environmental or biological variables are influencing this variation? How can we separate the influence of environmental variables on these spatial patterns from demographic factors such as immigration/emigration, propagule/offspring dispersal, zoogeography, etc.? If fish communities vary at large spatial scales as much or more than they do among major habitat types, how should monitoring and research studies incorporate this scale of variation into their experimental design?

Temporal patterns of fish community variation may reflect an effect of the 1993 Flood. The year 1994 was distinct from all other years within our time series, and the multigear index was especially useful for identifying this pattern. Observations made during the 1993 Flood suggest that several fishes took advantage of increased access to floodplain habitats for feeding and reproduction, and many appeared to produce exceptional year classes (National Biological Service et al. 1994). In the time series we examined (1994 to 2002), common carp, freshwater drum, and black crappie had their peak abundance in 1994, possibly as a result of successful reproduction in 1993. Other species had their lowest abundance in 1994,

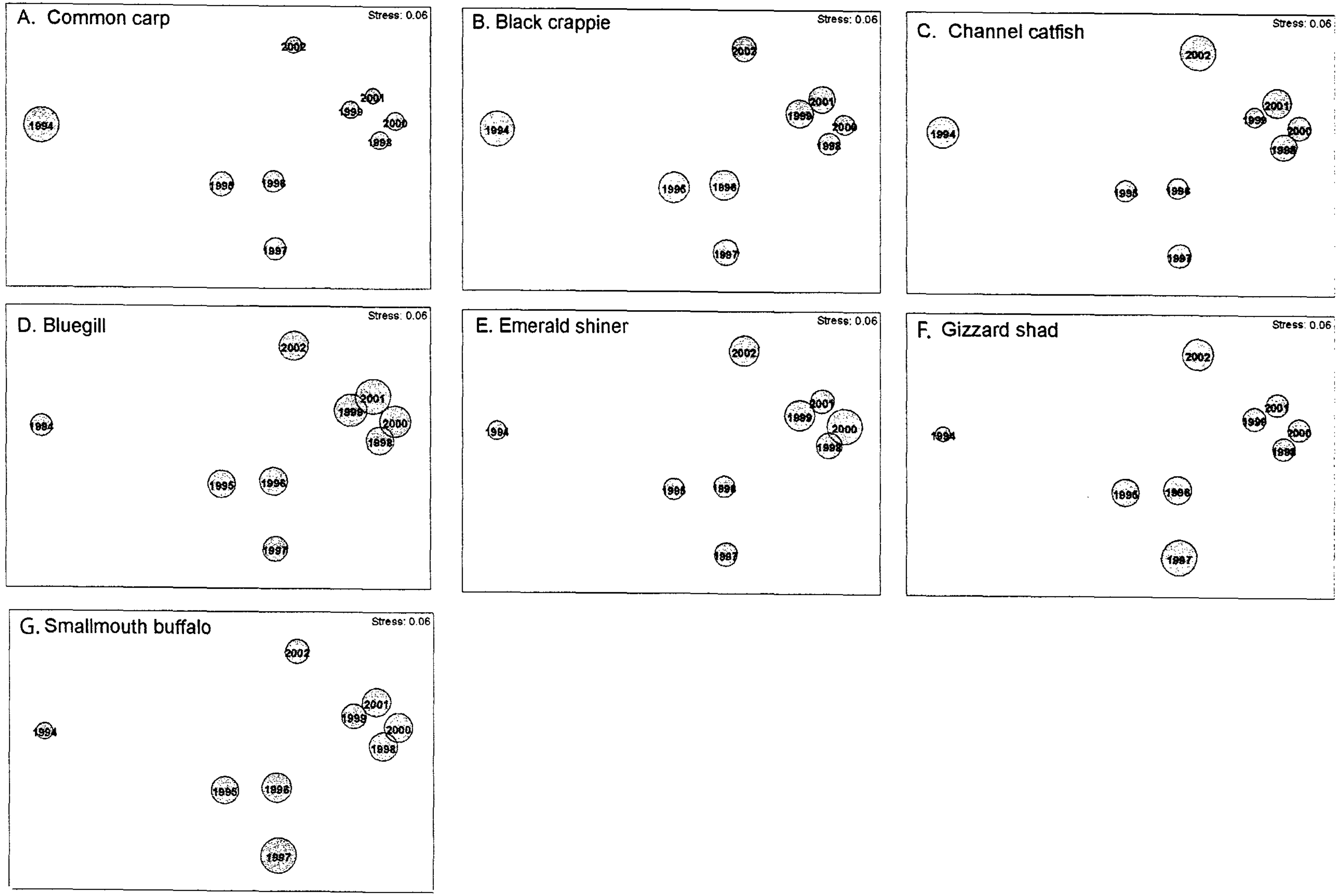

Figure 9. Nonmetric multidimensional scaling ordination of fish community structure data, indexed by multiple gears, and averaged by year across all resource trend areas for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Ecological similarity was measured using the Bray-Curtis Similarity metric. The ordination is identical to Figure 7, but overlaid with the relative abundance of seven fish species (A = common carp [*Cyprinus carpio*]; B = black crappie [*Pomoxis nigromaculatus*]; C = channel catfish [*Ictalurus punctatus*]; D = bluegill [*Lepomis macrochirus*]; E = emerald shiner [*Notropis atherinoides*]; F = gizzard shad [*Dorosoma cepedianum*]; and G = smallmouth buffalo [*Ictiobus bubalus*]) associated strongly with variation among years. Size of the circles is directly proportional to the abundance of each species for the specified year.

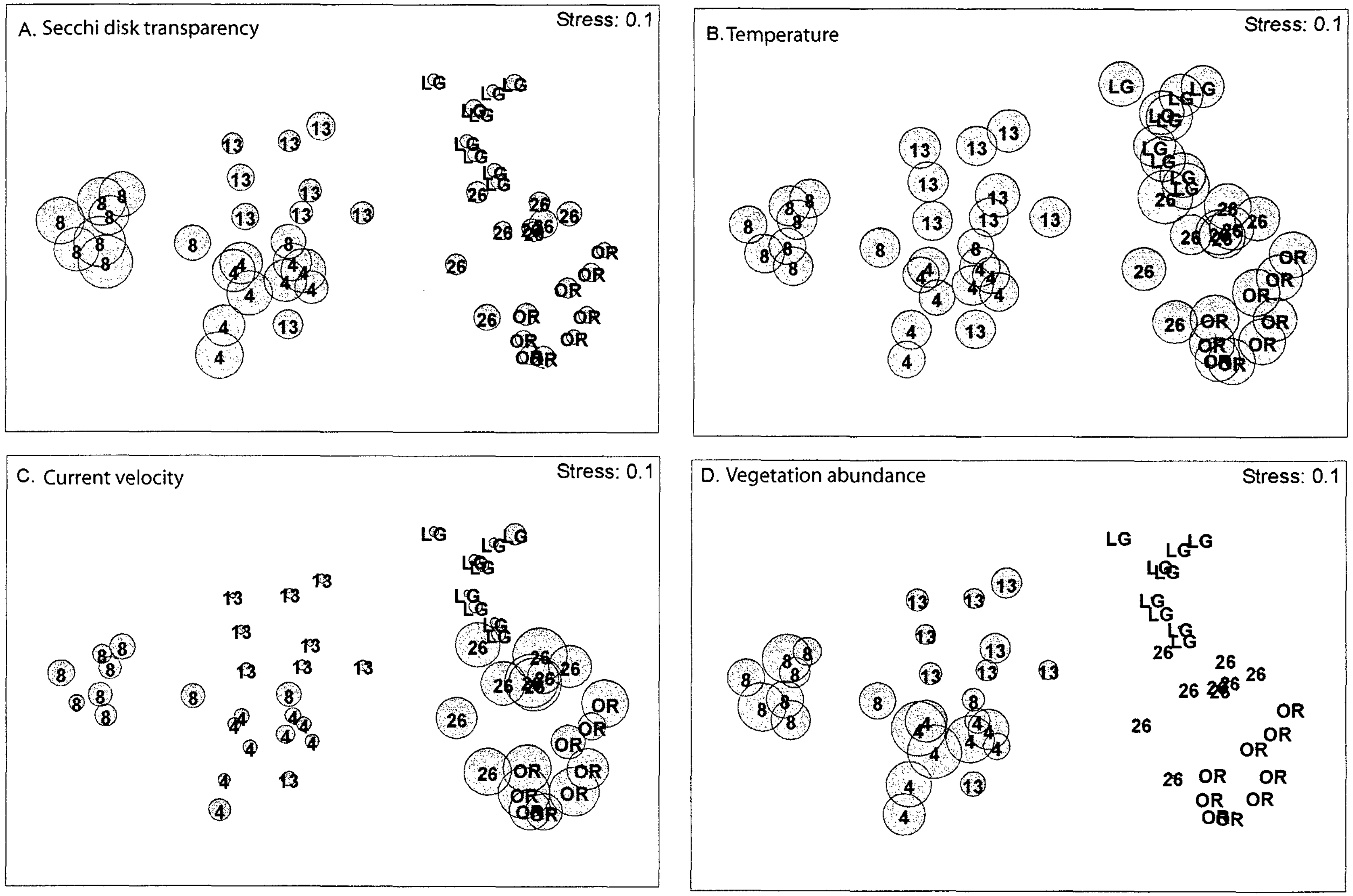

Figure 10. Nonmetric multidimensional scaling ordination of fish community structure data (square root catch/15 min of day electrofishing) for the Upper Mississippi River System collected by the Long Term Resource Monitoring Program, 1994–2002. Ecological similarity was measured using the Bray-Curtis Similarity metric. The ordination is identical to Figure 5 but with environmental conditions overlaid on the ordination to demonstrate associations across resource trend areas and years. Size of each circle reflects the mean value of each habitat factor (A = Secchi disk transparency, B = temperature, C = current velocity, and D = vegetation abundance) for each regional trend area (4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool, and OR = Open River Reach) and year.

possibly as a result of dramatic changes to habitat associated with the flood such as reductions in aquatic vegetation (Spink and Rogers 1996) and sedimentation effects (National Biological Service et al. 1994). Given the magnitude of the 1993 Flood, the relatively modest amount of temporal variation of UMRS fish communities further emphasizes the importance of the spatial variation observed.

Our use of a multigear index of fish community structure was novel and should be further examined as a potential useful method for examining community dynamics. Because several questions regarding the efficacy of this approach need to be addressed, we limited our use of this index to a secondary and supportive role to the more conservative analysis conducted with day electrofishing data alone. The results from the multigear analyses were, in general, corroborative of those from day electrofishing. Therefore, we believe further investigation into this analysis technique is warranted.

Implications for LTRMP

Our study demonstrated that LTRMP fish data can be used to detect variation in community composition and structure through space and time. We were able to detect temporal variation that was consistent across all RTA, while simultaneously detecting large-scale spatial variation. Additionally, we were able to correlate large-scale spatial patterns with environmental variables measured locally within each river reach. This last result points to the importance of the habitat data collected during fish monitoring, including observational data (i.e., vegetation cover and density). Finally, our analyses suggest that further examination of spatial variability of fish communities and habitat in the UMRS may yield important insights into ecological dynamics and function within this river-floodplain ecosystem.

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References

Carlson, B. D., D. B. Propst, D. J. Synes, and R. S. Jackson. 1995. Economic impact of recreation on the Upper Mississippi River System. Prepared for the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Technical Report EL-95-16.

Chick, J. H., and M. A. Pegg. 2004. Long Term Resource Monitoring Program outpool fisheries analysis: Final report. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, March 2004. LTRMP 2004-T001. 21 pp.

Clarke, K. R., and R. M. Warwick. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratories, Plymouth, United Kingdom.

Gammon, J. R., and T. P. Simon. 2000. Variation in a great river index of biotic integrity over a 20-year period. Hydrobiologia 422/423:291–304.

Gutreuter, S., R. Burkhardt, and K. Lubinski. 1995. Long Term Resource Monitoring Program procedures: Fish monitoring. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin. LTRMP 95-P002-1. 42 pp. + Appendixes A–J.

Ickes, B. S., and R. W. Burkhardt. 2002. Evaluation and proposed refinement of the sampling design for the Long Term Resource Monitoring Program's fish component. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, October 2002. LTRMP 2002-T001. 17 pp. + Appendixes A–E. CD-ROM included. (NTIS # PB2003-500042)

Koel, T. M. 2001. Classification of Upper Mississippi River pools based on contiguous aquatic/geomorphic habitats. Journal of Freshwater Ecology 16:159–170.

Lubinski, K, R. Burkhardt, J. Sauer, D. Soballe, and Y. Yin. 2001. Initial analyses of change detection capabilities and data redundancies in the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, September 2001. LTRMP 2001-T001. 23 pp. + Appendixes A–E (NTIS # PB2002-100123).

National Biological Service, Illinois Natural History Survey, Iowa Department of Natural Resources, and Wisconsin Department of Natural Resources. 1994. Long Term Resource Monitoring Program 1993 Flood observations. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, December 1994. LTRMP 94-S011. 190 pp. (NTIS #PB95-181582).

Primer-E Ltd. 2001. Primer for Windows Version 5.2.4. Plymouth, United Kingdom.

Pegg, M. A., and C. L. Pierce. 2002. Fish community structure in the Missouri and Lower Yellowstone rivers in relation to flow characteristics. Hydrobiologia 479:155–167.

Pegg, M. A., and M. A. McClelland. 2004. Assessment of spatial and temporal fish community patterns in the Illinois River. Ecology of Freshwater Fish 13:125–135.

Schiemer, F. 2000. Fish as indicators for the assessment of ecological integrity of large rivers. Hydrobiologia 422/423:271–278.

Schmutz, S., M. Kaufmann, B. Vogel, M. Jungwirth, and S. Muhar. 2000. A multi-level concept for fish-based, river-type-specific assessment of ecological integrity. Hydrobiologia 422/423:279–289.

Sparks, R. E., J. C. Nelson, and Y. Yin. 1998. Naturalization of the flood regime in regulated rivers: the case of the upper Mississippi River. Bioscience 48:706–720.

Spink, A., and S. Rogers. 1996. The effects of a record flood on the aquatic vegetation of the Upper Mississippi River System: some preliminary findings. Hydrobiologia 340:51–57.

U.S. Army Corps of Engineers. 1997. Report to Congress, An evaluation of the Upper Mississippi River System Environmental Management Program, December 1997. Chapters 1–8 + Appendixes A-B.

U.S. Fish and Wildlife Service. 1993. Operating Plan for the Upper Mississippi River System Long Term Resource Monitoring Program. Environmental Management Technical Center, Onalaska, Wisconsin, Revised September 1993. EMTC 91-P002R. 179 pp. (NTIS #PB94-160199)

U.S. Geological Survey. 1999. Ecological status and trends of the Upper Mississippi River System 1998: a report of the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, April 1999. LTRMP 99-T001. 236 pp.

Welcomme, R. L. 1979. Fisheries ecology of floodplain rivers. Longman Group Limited. London. 317 pp.

Welcomme, R. L. 1985. River fisheries. Food and Agriculture Organization, United Nations, Rome. FAO Fisheries Technical Paper 262.

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13. ABSTRACT (Maximum 200 words)

Variation in community composition (presence/absence data) and structure (relative abundance) of Upper Mississippi River fishes was assessed using data from the Long Term Resource Monitoring Program collected from 1994 to 2002. Community composition of fishes varied more in space than through time. We found substantial variation in community composition across two spatial scales: large-scale differences between upper and lower river reaches and small-scale differences among individual regional trend areas (RTA). Community structure (relative abundance data) of fishes also varied more through space than through time. We found substantial variation in fish community structure at three spatial scales: (1) large-scale differences between upper and lower river reaches, (2) differences among individual RTA, and (3) differences among habitat strata, with backwaters having a distinct community structure relative to the main channel and side channels. When averaged across all RTA, fish community structure in 1994 and 1995 was distinct from all other years, possibly as a result of the 1993 Flood. Fish community structure observations for each RTA and year correlated with the environmental variables measured at each sample site. A canonical approach revealed that the combination of Secchi depth, water temperature, current velocity, and vegetation abundance had the greatest correlation with community structure.

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.